

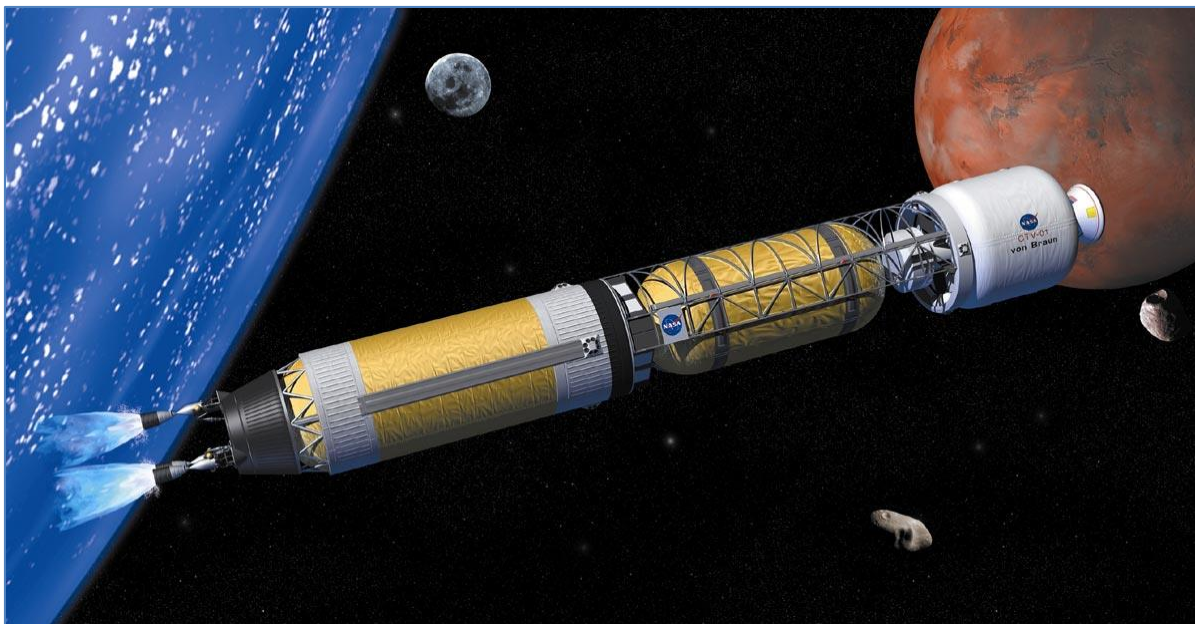
Nuclear Thermal Propulsion Fuel Rod Testing and Optimization

A composite space-themed background. In the foreground, the blue and white horizon of Earth curves across the bottom left. Behind it, the grey, cratered surface of the Moon is visible. To the right of the Moon is the reddish-orange planet Mars. In the upper right corner, a vibrant, multi-colored nebula (orange, yellow, green, blue) glows against the blackness of space, which is filled with distant stars and small asteroids.

Adam Dziubanek
University of Alabama in Huntsville
Marshall Space Flight Center

A small satellite with two large solar panel arrays is shown in orbit in the lower right quadrant of the image.

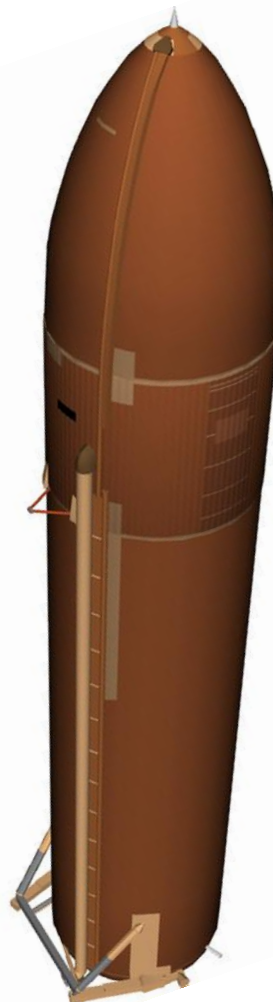
- **Viable concept for mars mission**
- **High ISP (~900 or more) roughly twice as much as chemical rockets**
- **Used for in space propulsion**



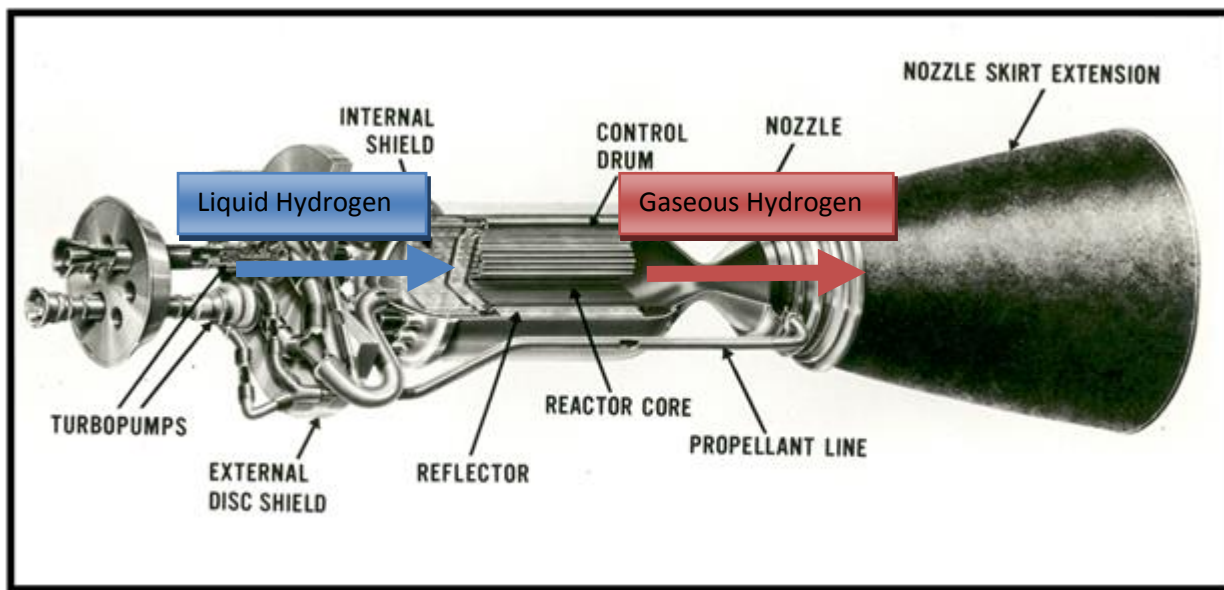
- **Nuclear fission reactions has a high energy yield**
- **12 fl oz of uranium fission**



= 50 X

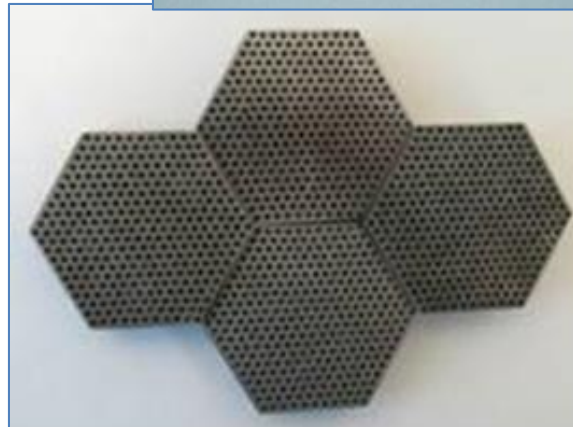
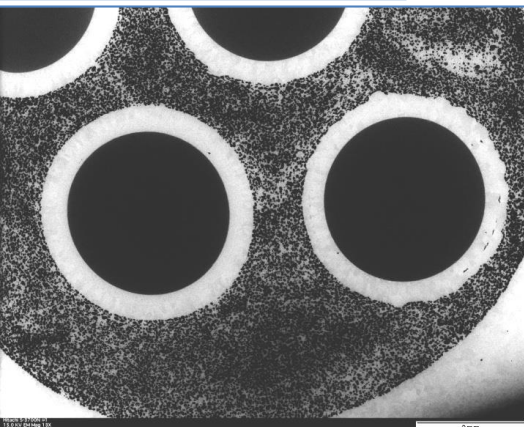
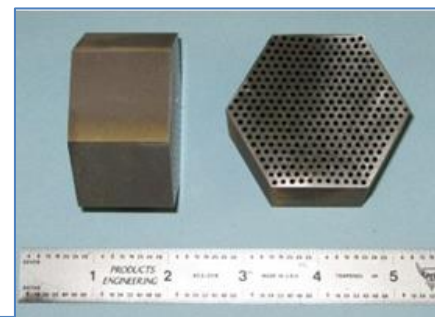
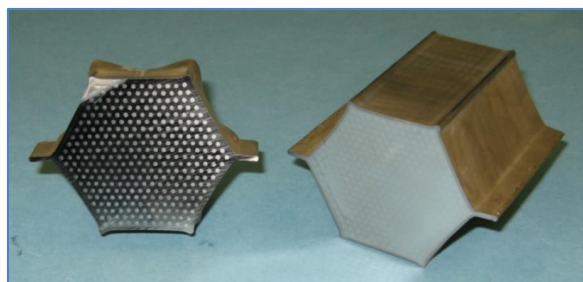
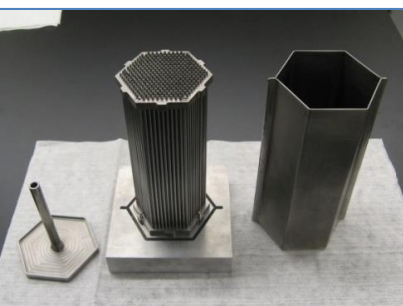


- **NERVA Rocket Engine**
- **High ISP**
- **Liquid hydrogen used for fuel**
- **Low Enriched Uranium (LEU)**

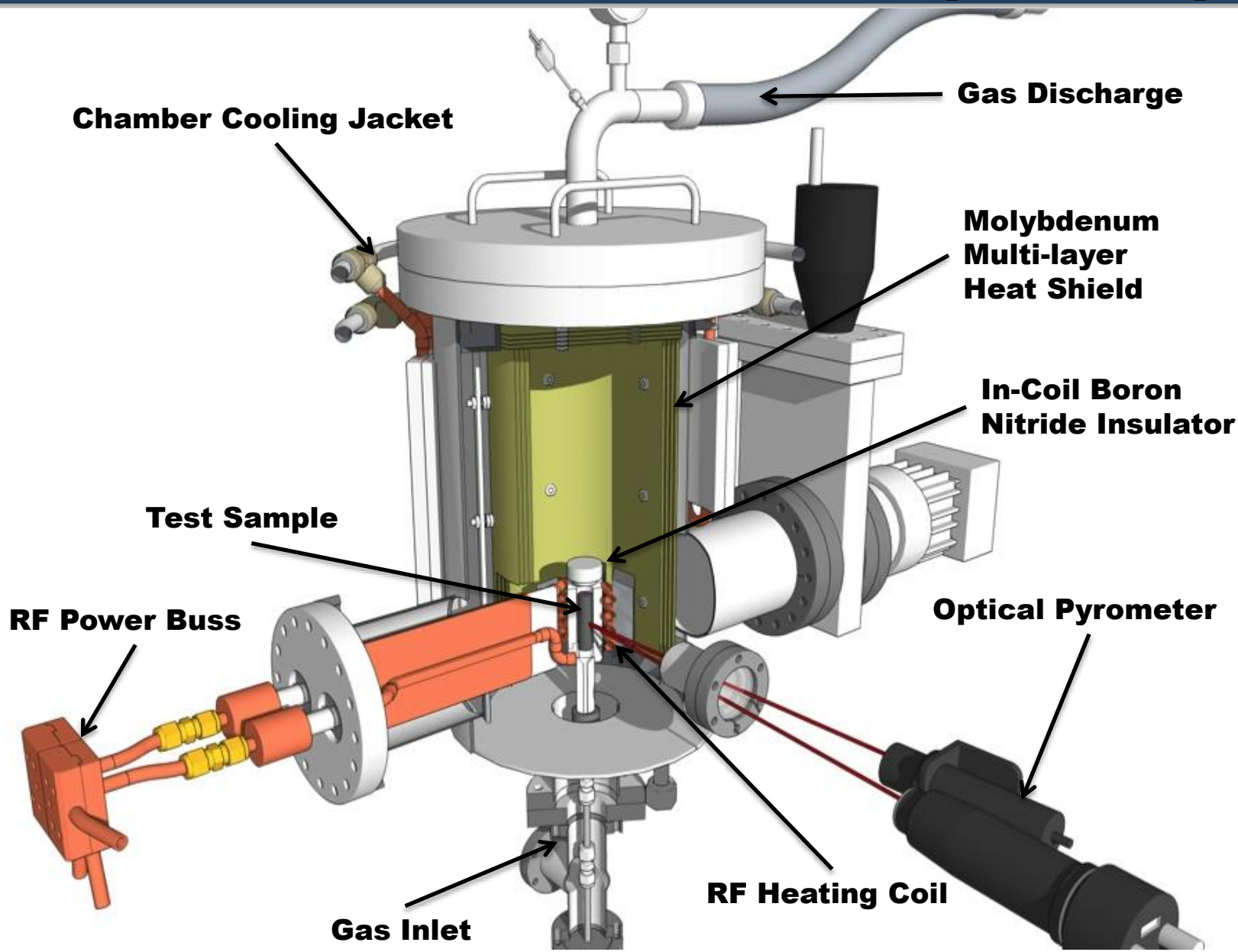


Fuel Rod Development

- **Critical need for fuel rod development**
- **Reactor temperatures up to 3000K**
- **Hydrogen is highly reactive with most materials at high temperatures**
- **Limited data covering the effects of high-temp H₂**
- **Cladded tungsten surface**

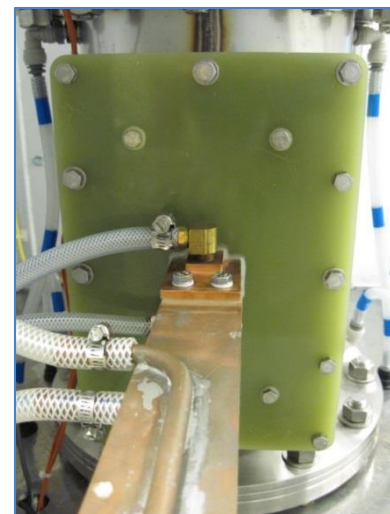
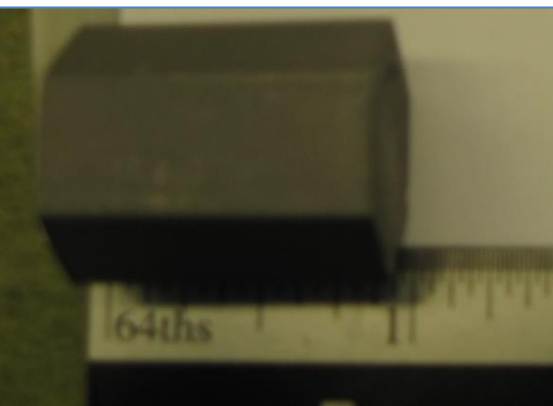
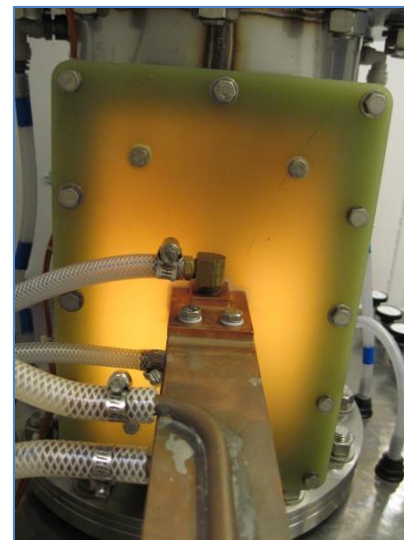
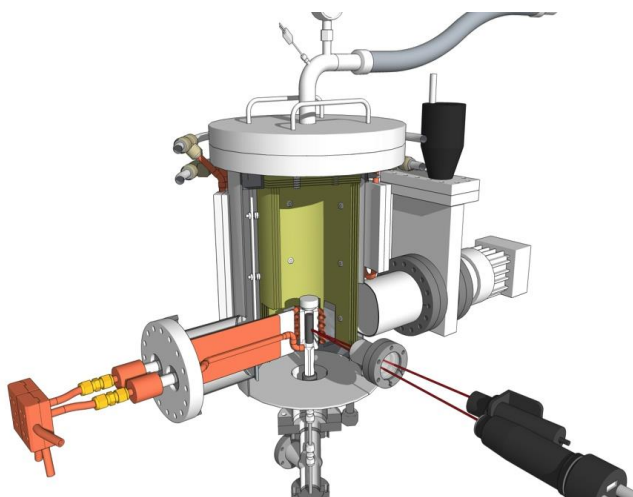


Compact Fuel Element Environment Tester (CFEET)



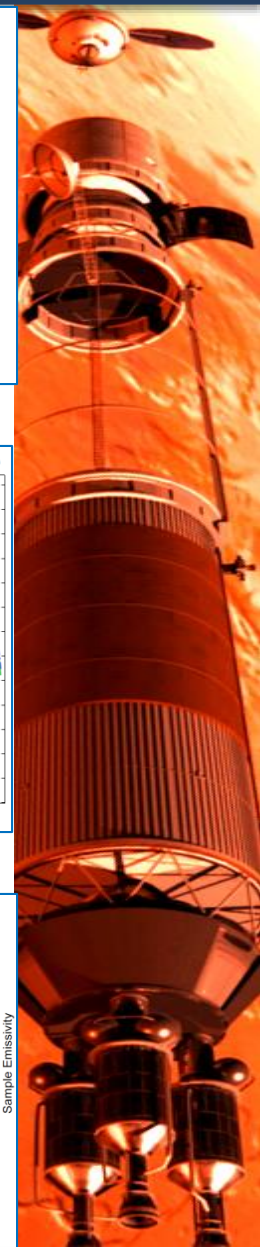
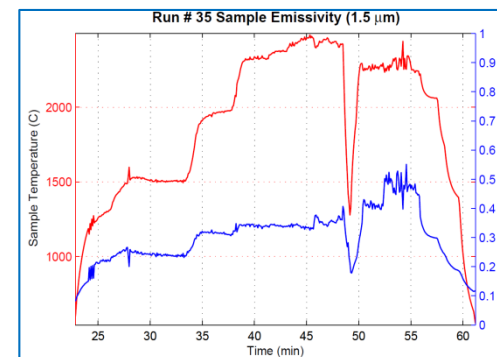
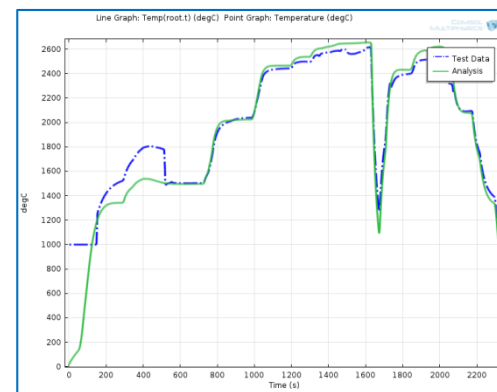
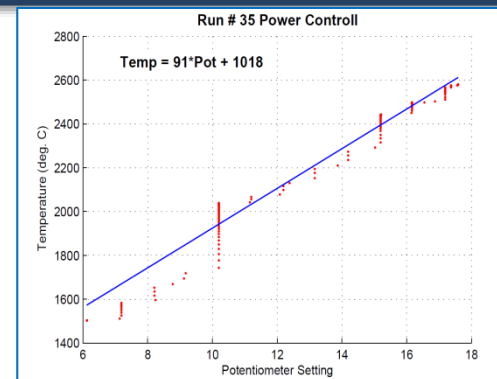
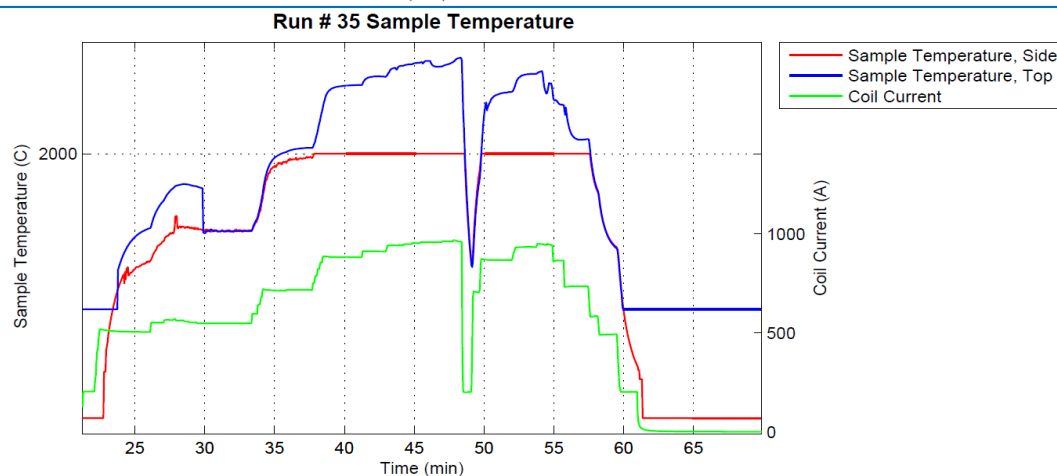
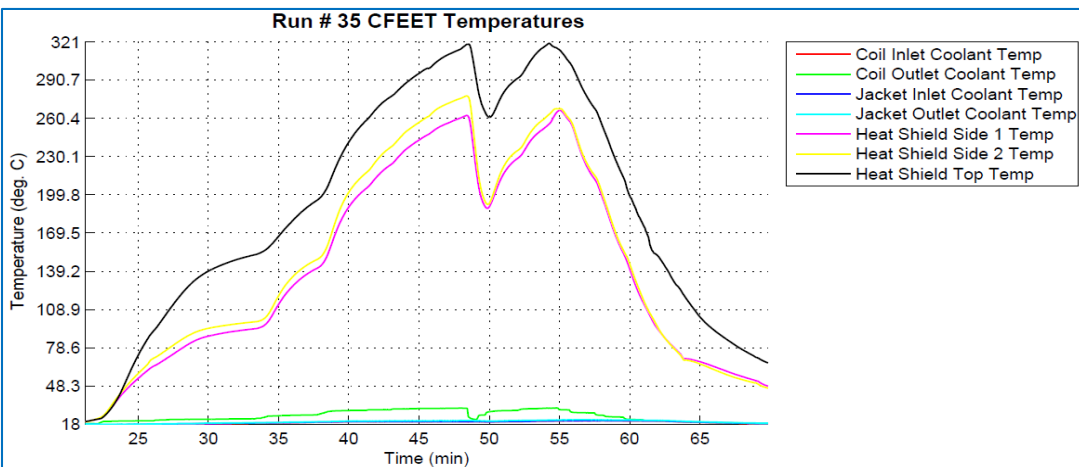
CFEET Optimization

- **Verify Pyrometer readings**
- **Material used with known melting point**



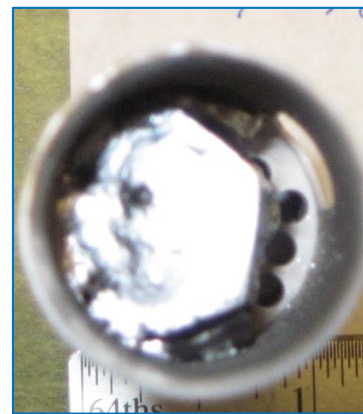
CFEET Optimization

• Data and analysis



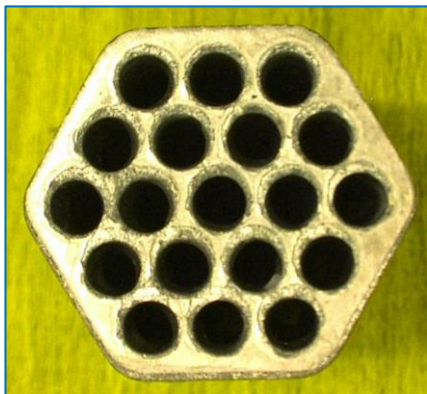
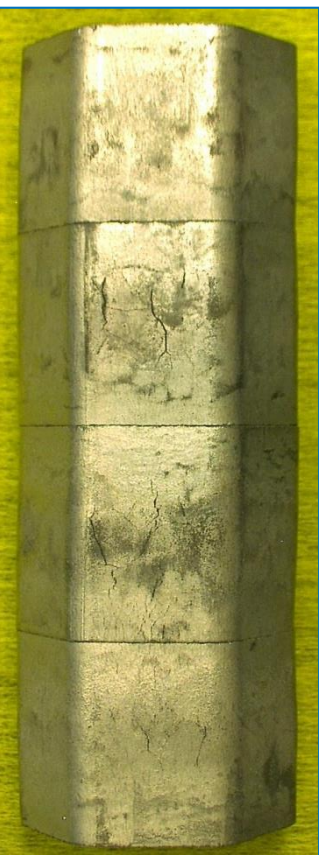
CFEET Optimization

- **Post test**
- **Molybdenum melted**
- **Pyrometers successfully calibrated**



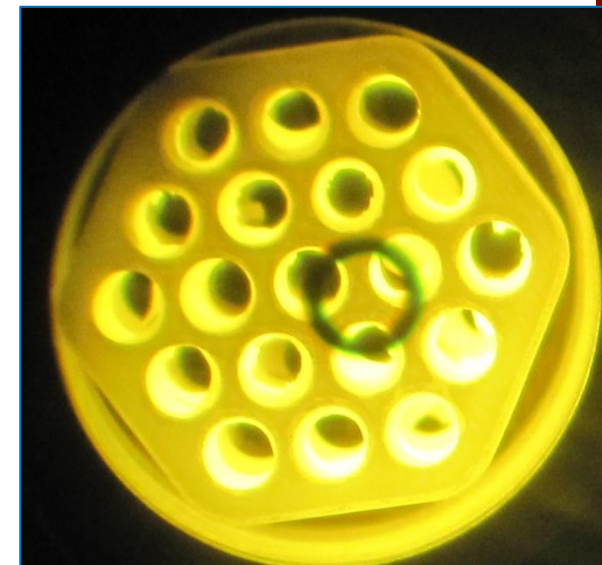
CFEET Testing

- **Pre test pictures of LEU sample**



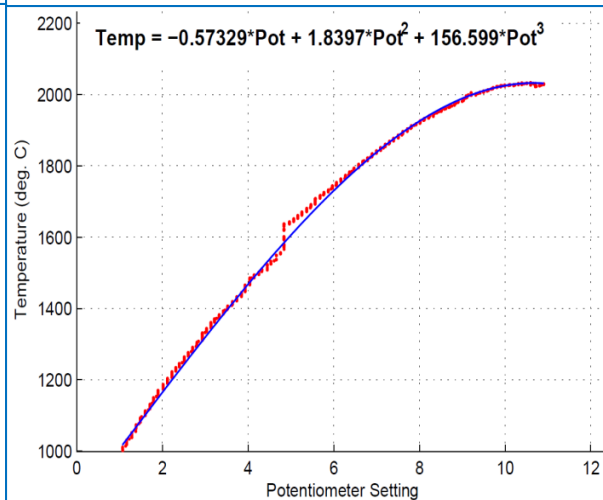
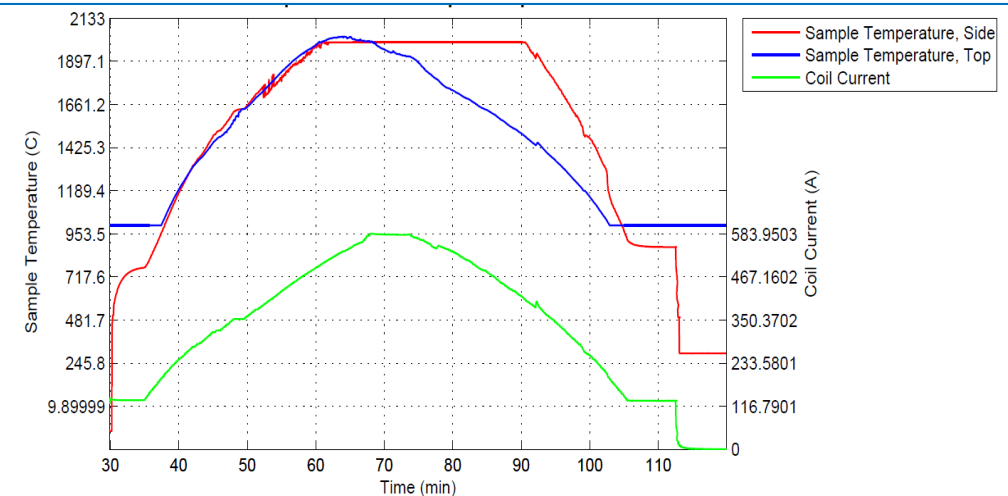
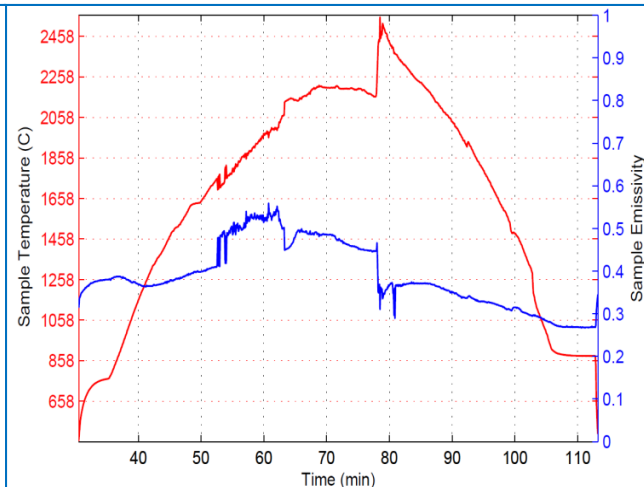
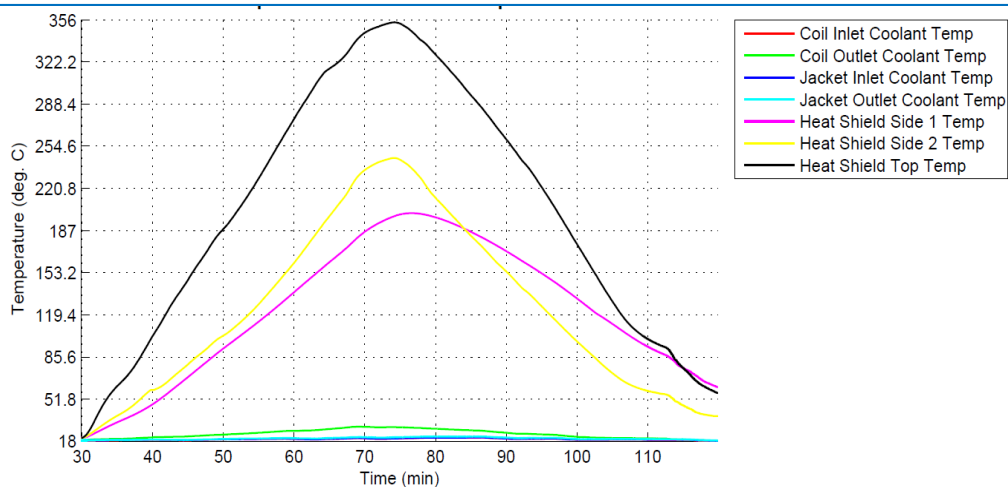
CFEET Testing

- **Green flame during testing**
- **Pyrometer reading up to 2800°C**



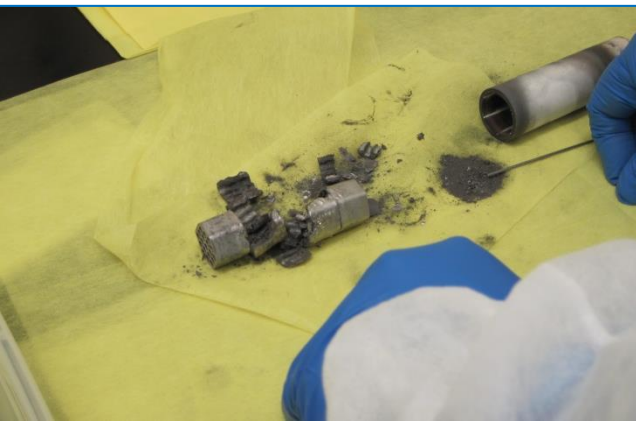
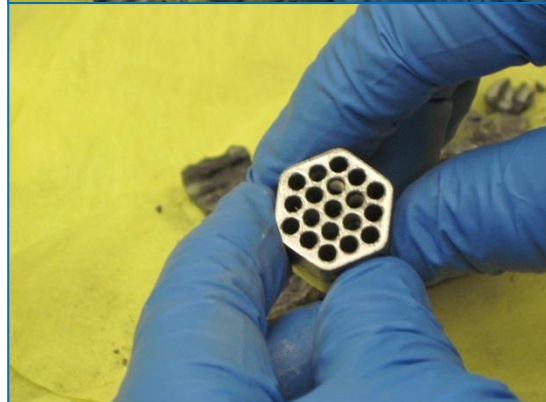
CFEET Testing

• Data and Analysis



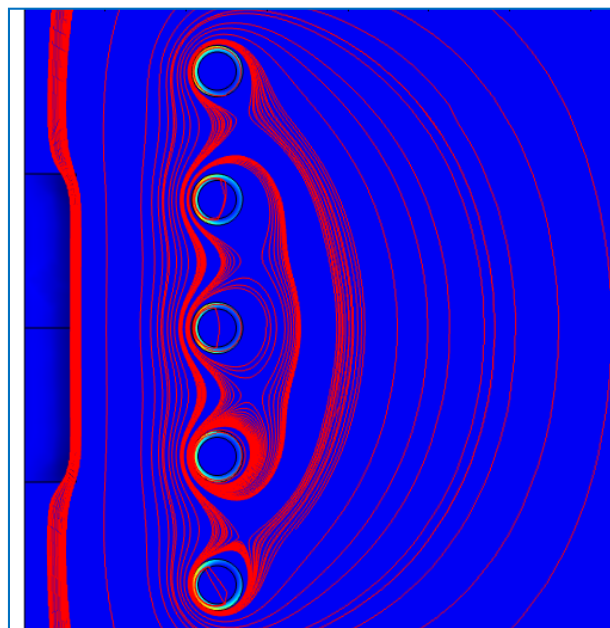
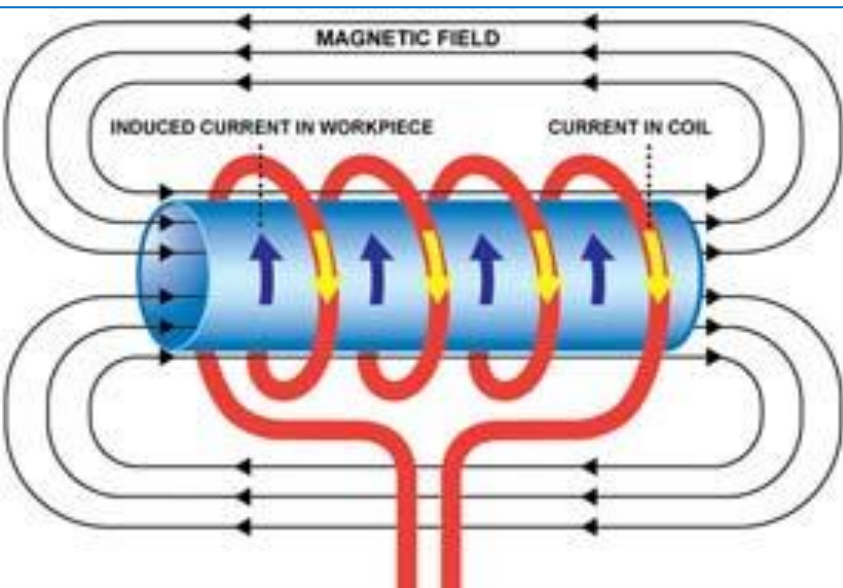
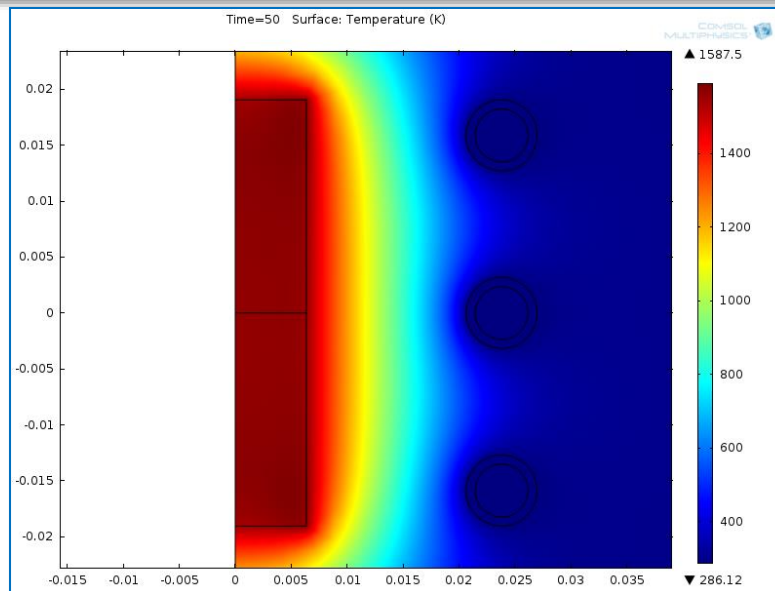
CFEET Testing

- **Post test pictures of LEU sample**
- **Possible causes?**
- **Failed before final temperature was reached**
- **Fuel rod designed to withstand temperatures of 3000K**



CFEET Testing

- **Focal point theory**
- **RF power supply creates an AC current on the sample**
- **The current flows against the resistivity of the metal, generating heat**

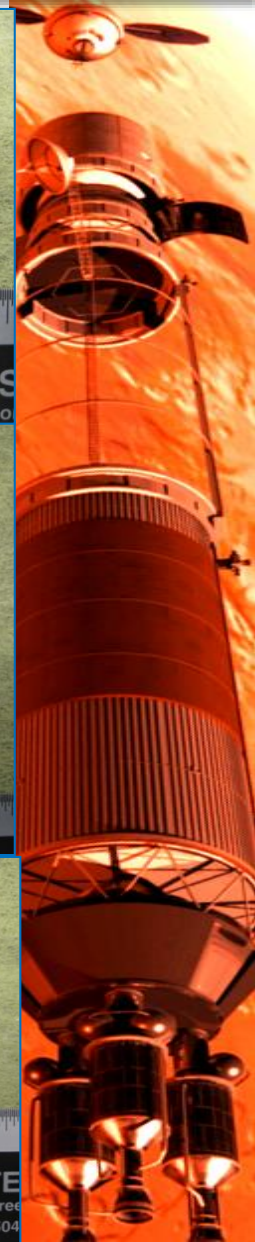


CFEET Testing

- Possible solutions
- Tungsten susceptor
- Coil sizing



Figure 9. 308 stainless steel sample before and after melting at 1500°C.



Conclusion



- **NTP offers a safe and effective way to get to Mars**
- **CFEET is a reliable test bed for NTP fuel rod design**
- **Acknowledgements: Carolyn Russell, Robert Hickman, Doug Trent, Dr. Mireles**



- Protection from Radiation
 - Time
 - Distance (Crew at the front, fuel tanks, space trusses, then engine)
 - Shielding (Shadow Shield)
- What if it explodes?
 - Water could activate the reactor

